2. Chapter Two, Summary/Conclusions

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2.1. An Overview of the Results and Conclusions of the Analysis

A study of site geography, seismology, meteorology, hydrology, demography and adjacent facilities, which includes the C-AD accelerators and experimental areas, shows:

- about 30% of the BNL site is developed with buildings and roads and the balance is undeveloped Pine Barrens forest
- it is the consensus of seismologists that no significant earthquakes are to be expected in the near future
- the climate is temperate
- the Upper Glacial aquifer is a widely used public and private water supply
- radiation from accelerator and experimental area operations will not affect occupants located at the closest occupied non-C-AD facilities

The design criteria, as-built characteristics and supporting systems with safety-significant functions are as follows:

- the design of the accelerators is such that they are capable of accelerating particles that range in mass from protons to Au ions

- nucleon energies within the accelerated particle range from 0.04 to 250 GeV/amu, and beam intensity ranges from 10^3 to 10^{14} particles per pulse; this design provides the most versatile experimental beams and ranges of energies and intensities practicable
- the as-built complex consists of a set of warm-magnet based and superconducting-magnet based accelerators including a Linac, two Tandem van De Graaffs, two synchrotrons and two collider rings
- there are adjacent utility support buildings for power systems, mechanical equipment and cooling systems for the accelerators and the experiments
- these accelerators all have an injection system, an accelerating system, a beam-scraping or internal dump system and an extraction system and they are connected by a series of transfer beam-lines
- the collider rings contain internal extraction systems that send aborted beam to internal beam dumps
- the as-built complex also includes multiple experimental areas that envelop external experimental beam-lines, a superconducting storage ring, beam collimators, target halls, beam stops and an experimental support laboratory
- the collider ring encloses internal beam-collision regions for the RHIC experiments; that is, beam is not extracted out of the RHIC tunnel like at Linac, TVDG, Booster and AGS
- the as-built experimental halls for beam lines and detectors range in size from several thousand square feet to 5 acres, and experimental particle detectors range in cost from hundreds of thousands to hundreds of millions of dollars

- the experimental support laboratory at the NSRL facility also houses equipment for biological sample preparation and dosimetry analysis, and has temporary animal holding facilities
- supporting systems with safety-significant functions include access control systems and the fire protection systems
- the design criteria for the access control systems are that they are redundant, failsafe and have backup; either the system prohibits access or it prevents radiation levels from rising to unacceptable levels
- the access controls systems may also be used to evacuate areas or prohibit entry to areas that have oxygen deficiency
- the design criteria for fire protection systems are that alarms and sprinklers are supervised for circuit trouble and report to the site Fire/Rescue Group, building occupants can hear and/or see alarms throughout the facility, and manual fire alarm pull boxes are located at each exit

Physical features that minimize the presence of hazardous environments and ensure chemical and radiation exposures are kept ALARA during operation, maintenance and facility modification include:

- for radiation: radiation interlocks; gate interlocks; sectionalizing gates; key trees; bio-identification systems; crash cords; audible and visual warnings for beam; fully enclosed primary-beam lines, beam-collision regions or primary-beam target areas; shielding; fencing and posting
- for airborne hazards: once-through and recirculating Biological Safety Cabinets with HEPA filters, chemical hoods, individual laboratory ventilation or target hall

ventilation; short-lived airborne radioactivity is re-circulated in beam lines and accelerators; with the exception of the NSRL target room, stack-type air-emissions from accelerators and beam lines are prevented

- for ALARA: water-resilient caps over activated-soil locations; multi-leg penetrations and labyrinths; re-entrant cavities with movable shields at face of beam stops; and experiment/sample translators or remote operations when applicable
- for electrical safety: compliance with the National Electric Code for non-experimental power-distribution systems;[1] for experimental equipment, a comprehensive set of electrical safety requirements is used, for example, fused circuitry in experimental equipment, emergency-off controls for power, coordinated over-current protection, proper conductor sizing, proper grounding, etc.[2]
- for life-safety and fire protection: manual fire alarm stations; smoke detection; fire alarms; sprinkler protection; fire-hose standpipes; electrical cable insulation and cable trays that meet the National Electrical Code; exits that meet the Life Safety Code; emergency lighting; and fire extinguishers
- for liquid effluents: sumps and sump alarms; drains connected to Sanitary Sewage System; cooling water make-up alarms; no outdoor tritiated-water piping; closed tritiated cooling-water systems; and back-flow preventers on supply water
- for biological safety: Biosafety Level 2 design, Class 2, Type A biological safety cabinets; HEPA filtered air circulation in the NSRL animal laboratory; separate

[1] During October and November 2003, an inspection at BNL led by the Occupational Health and Safety Administration showed areas where the National Electric Code is not being met. These areas have been identified, and either the condition has been fixed to meet code or the condition has been ameliorated to a safe state in accordance with BNL requirements.
[2] Supplemental Electrical Safety Standard, Collider-Accelerator Department, C-AD Chief Electrical Engineer, November 27, 2000.

ventilation in the cell laboratory; and poured-resinous, seamless floors and washable walls in the animal laboratory

The organizational and management structure the Collider-Accelerator Department and a delineation of responsibilities for safety related actions assure safe operation of the accelerators and experimental areas. Controls for routine operations and emergency conditions are located in the Main Control Room in Building 911, a control room that is staffed around-the-clock by qualified Operators and an Operations Coordinator during operations. Procedures for routine operation and emergency conditions are delineated in the Collider-Accelerator Operations Procedure Manual, which is a controlled document.

Specific operations controls that prevent or mitigate accidents are the beam-loss monitoring systems. The purpose of these machine-protection-systems is to minimize beam loss and to help provide the required beam on target. The Collider-Accelerator Department management requires that inadvertent beam loss occur at levels that are as low as reasonably achievable with operational, economic and community factors taken into account. Specific operations procedures and protocols that prevent or mitigate accidents include Accelerator Safety Envelope procedures, sweep procedures to remove people from beam-enclosures prior to operations, access-control-system testing procedures, beam-loss ALARA procedures, lock-out tag-out procedures, fire-protection system testing protocols, soil-cap inspection procedures, experimental safety check-off lists, radiation safety check-off lists, and work-planning procedures.

Based on analysis, the risk of a serious injury from fire, radiation and electrical hazards at the accelerator and experimental facilities is considered insignificant. This is due to controls that are employed for hazard mitigation. A study of the credible challenges to controls and estimates of consequences in the event of corresponding failure showed that the risk of injury was unlikely. The credible maximum bounding accident scenarios for the C-AD accelerators and experimental areas show less than the design goal of 20 mrem per event to individuals in uncontrolled areas outside the shielded areas.[3] Risks to workers, the public and environment are considered insignificant for routine operations.

2.2. Comprehensiveness of the Safety Analysis

The C-AD SAD for accelerators and experimental areas is consistent with DOE Orders. It closely follows the prescription for an SAD given in Draft Accelerator Safety Implementation Guide for DOE O 420.2A, Safety of Accelerator Facilities, Office of Science, Department of Energy, August 2001.[4]

Fire protection systems and the access control systems are identified as safety significant. The Department's shielding policy is clearly stated.[5] Optimization methods are used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical controls.[6] Models used for dosimetric predictions in the SAD are described and are verified against actual measurements.[7, 8]

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[3] During routine RHIC operations, the RHIC berm is a Controlled Area. However, the access road into RHIC is uncontrolled. The short uncontrolled portion of road atop the berm is protected by Chipmunk radiation monitors. This area is the single exception to the 20 mrem C-AD shielding policy for protection against faults, and maximum fault dose on the roadway is estimated to be less than 50 mrem if a highly unlikely point loss occurs at that location.
[4] See http://www.rhichome.bnl.gov/AGS/Accel/SND/420Guide/Guide420.pdf
[5] See C-AD SAD Chapter 3, Section 3.2.7.1, Shielding Policy.
[6] See C-AD SAD Appendix 1, 10CFR835 ALARA Design Document for C-AD, http://www.rhichome.bnl.gov/AGS/Accel/SND/c-a_sad_and_ase.htm.
[7] See, for example, http://www.rhichome.bnl.gov/AGS/Accel/SND/C-ADSADReferences/ADtn414.pdf, Radiation Protection Studies during High Intensity Proton Running at AGS, Radiation Exposure around the AGS Ring and in the SEB Experimental Areas.

Significant occupational safety and health aspects and environmental aspects are identified and adequate controls are described.[9, 10, 11, 12]

The C-AD SAD clearly documents the safety and health aspects of all portions of the facility including the accelerators, beam lines, target or beam-collision areas and support facilities. The C-A Department organizational structure and ESH programs for commissioning and operation of C-AD accelerators and experimental areas are adequately described in the C-AD SAD.

2.3. Appropriateness of the Accelerator Safety Envelope

Using Chapter 4 of the C-AD SAD, associated risk assessment forms in Appendix 2, and results of the environmental assessments for these facilities, the Accelerator Safety Envelope (ASE) was developed according to requirements set forth in the BNL SBMS Subject Area, Accelerator Safety.

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[8] See, for example, RHIC Area Monitoring Report for CY 2000, http://www.rhichome.bnl.gov/AGS/Accel/SND/C-ADSADReferences/RHICDoseMeasurements.pdf.
[9] See C-AD Occupational Safety and Health Management System, http://www.rhichome.bnl.gov/AGS/Accel/SND/osh_management_system.htm
[10] See C-AD SAD Chapter 4.
[11] See C-AD Environmental Management System, http://www.rhichome.bnl.gov/AGS/Accel/SND/ems_at_c-a_department.htm.
[12] See Fire Hazards Analyses for C-AD, http://www.rhichome.bnl.gov/AGS/Accel/SND/fire_hazards_analyses.htm.